

Considering Variability When Looking for Trends

Y'all Be Careful Now!

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Roy J. Irwin, WRD, NPS



Two Airplanes Cleared To Land

- On the Same Runway, Same Time
- Opposite Directions
- Pilot Complains, The Tower, Realizing the Mistake Said
- Oops....Hmm....I Guess I Did.....
- Well.....Y'all Be Careful Now!

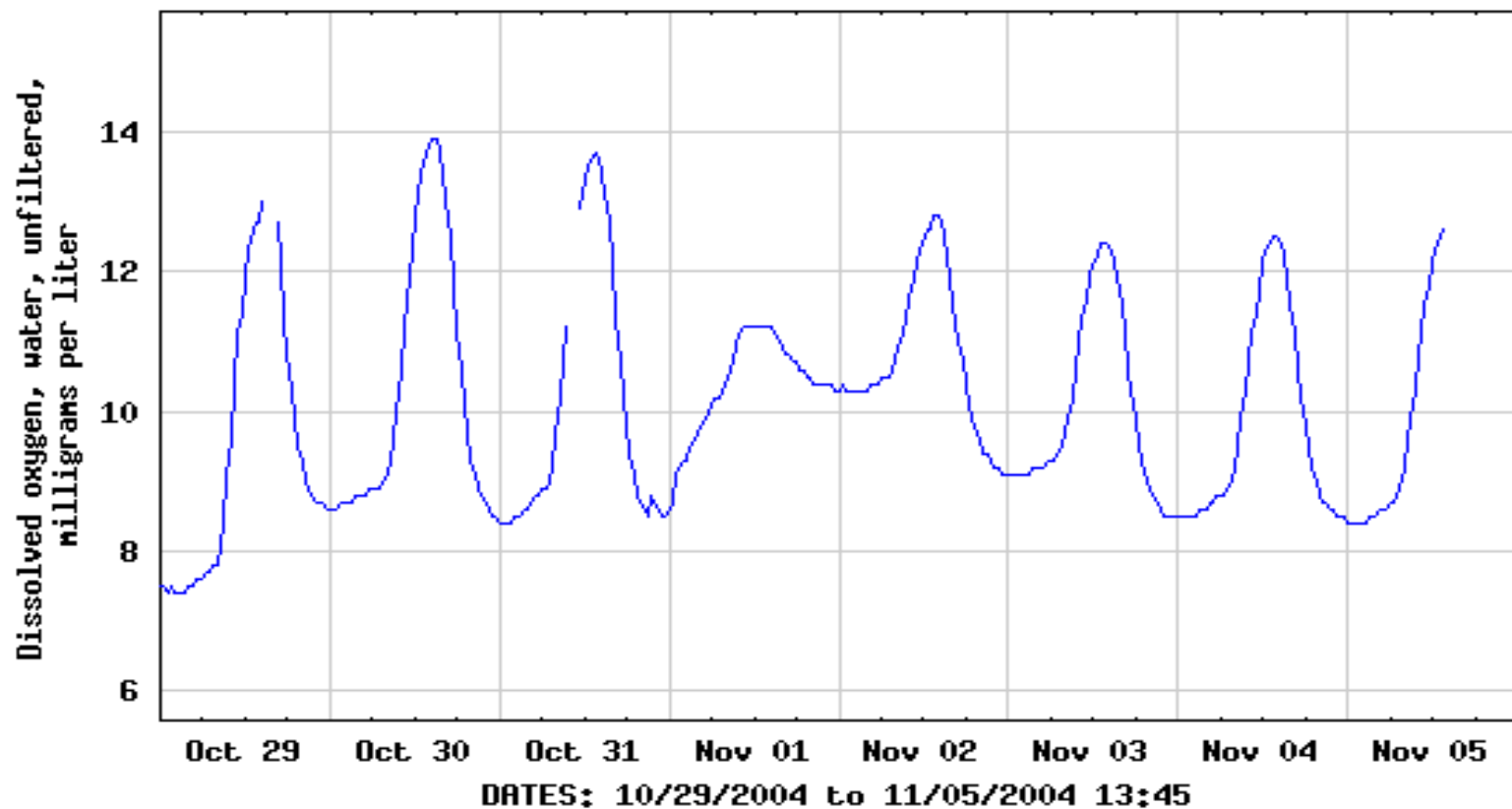
Monitoring For Trends Is Tricky

- You Need to Plan Carefully and
- Understand Variability: Time and Space
- Past Assumptions Have Been Wrong
- Try to Make Sense (Even in Gov't)
- Get Data That Will Be Useful
- Not Easy, Takes Careful Thought
- Diel = Diurnal = Regular 24 Hour Pattern
- Some Cycles Well Known:

Dissolved Oxygen Diel Well Known



USGS 06711565 SOUTH PLATTE RIVER AT ENGLEWOOD, CO.

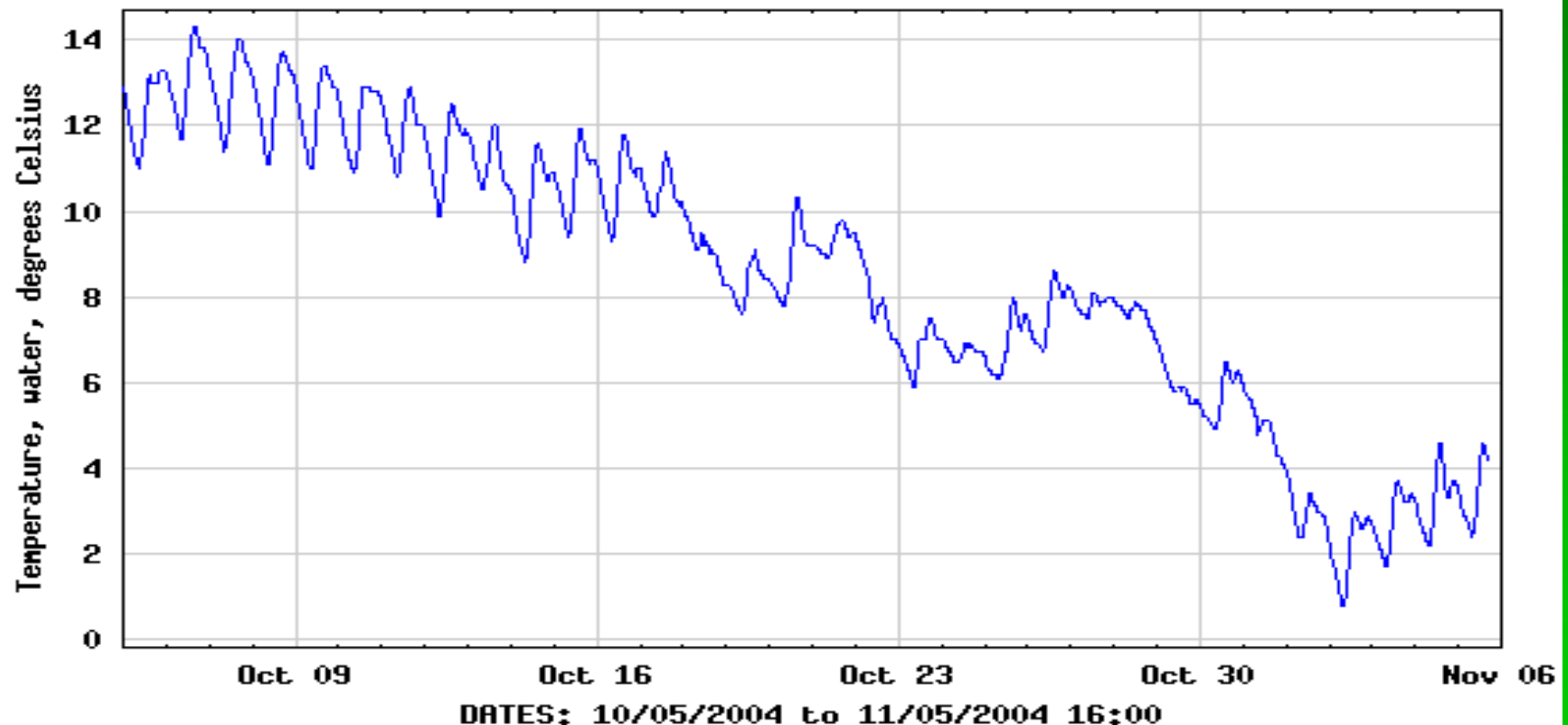


Provisional Data Subject to Revision

Temperature Diel Plus Seasonal



USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO.

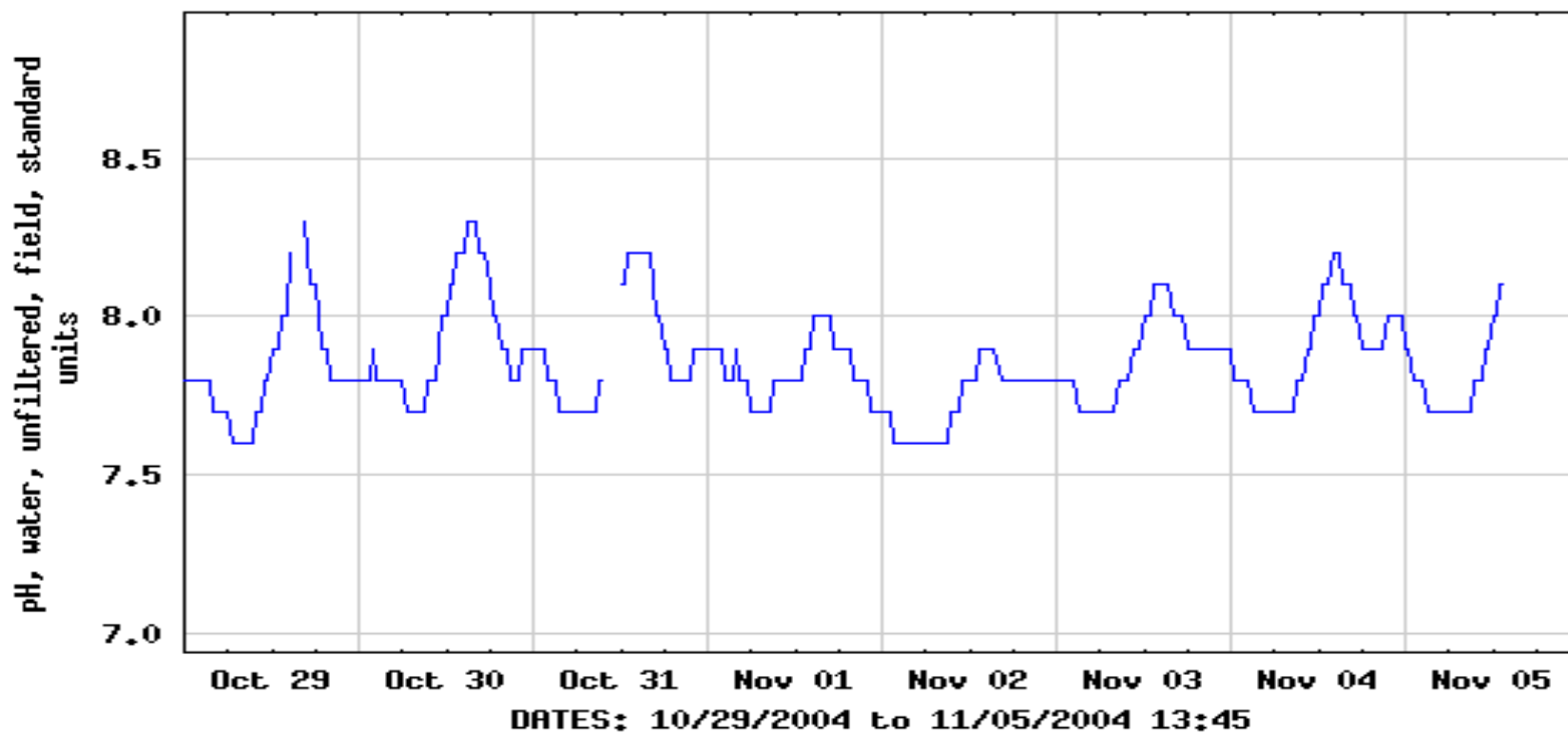


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Daytime Photosynthesis Drives Up pH



USGS 06711565 SOUTH PLATTE RIVER AT ENGLEWOOD, CO.



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Other Diel Cycles Not So Well Known

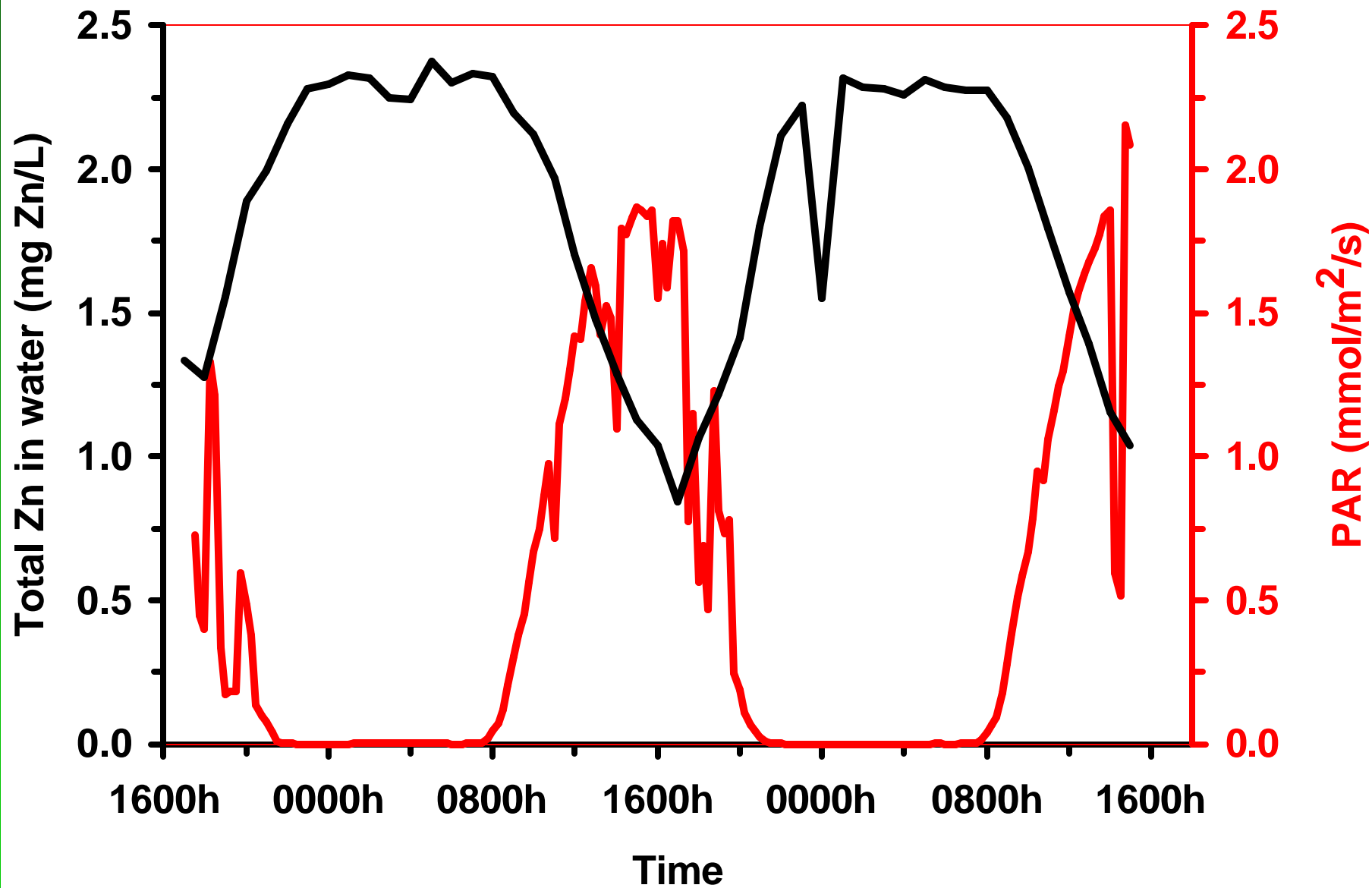
- Metals
- Nutrients
- Chlorophyll
- Flow
- Biological Metrics, Plankton Vertical Migration,
- But Some Mostly Seasonal

Metals Do It Too!

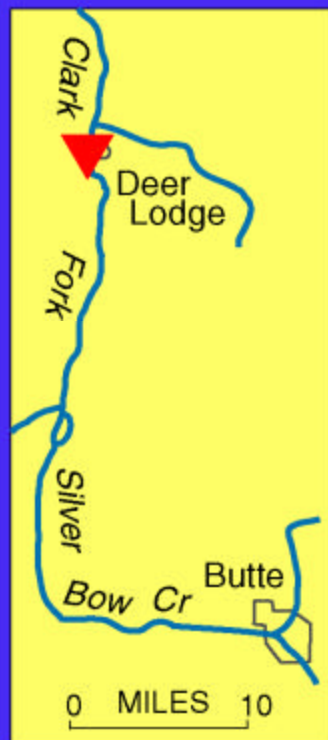
- Consider the following slides .
- Courtesy Jeff Morris, University of Wyoming and David Nimick, USGS, Helena, MT
- First Example Caused By Increase In pH.
- Most Biological and Chemical Changes are Driven by Sunlight Changes.

As Sunlight Increases, pH goes up and Dissolved Zinc Goes Down

- ✦ Sun Up, pH Up, Zinc Down
- ✦ Sundown, pH Down, Zinc Up
- ✦ Photosynthesis stops as PAR goes down.
- ✦ PAR = Photosynthetically Active Radiation



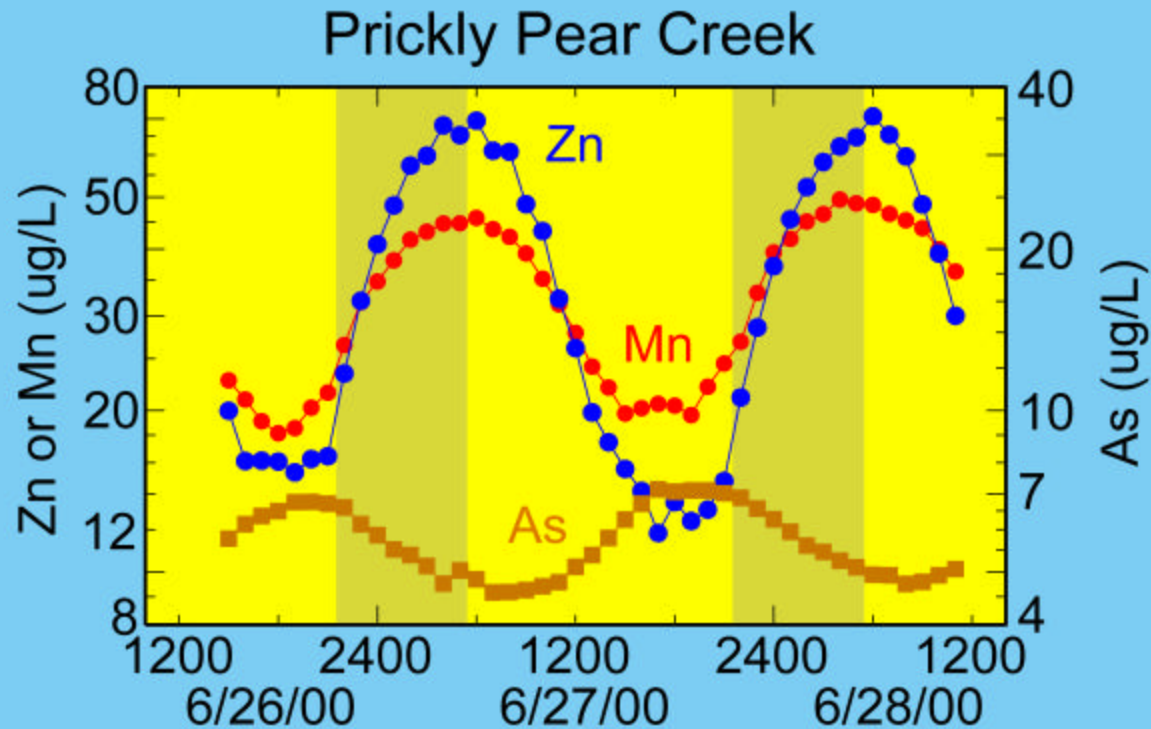
Diel metal sampling sites



▼ pH > 6.5
▼ pH < 6.0



As, Cd, Cu, Mn, Zn diel data



Nutrients Vs. Metals

- Plants and Animals Need Some Metals (Zinc, Copper)
- Metals Uptake In Algae Influenced By An Addition Of Nutrients
- Chemical, Physical, And Biological Drivers And Cofactors Can Be Complex: See Kristen Keteles

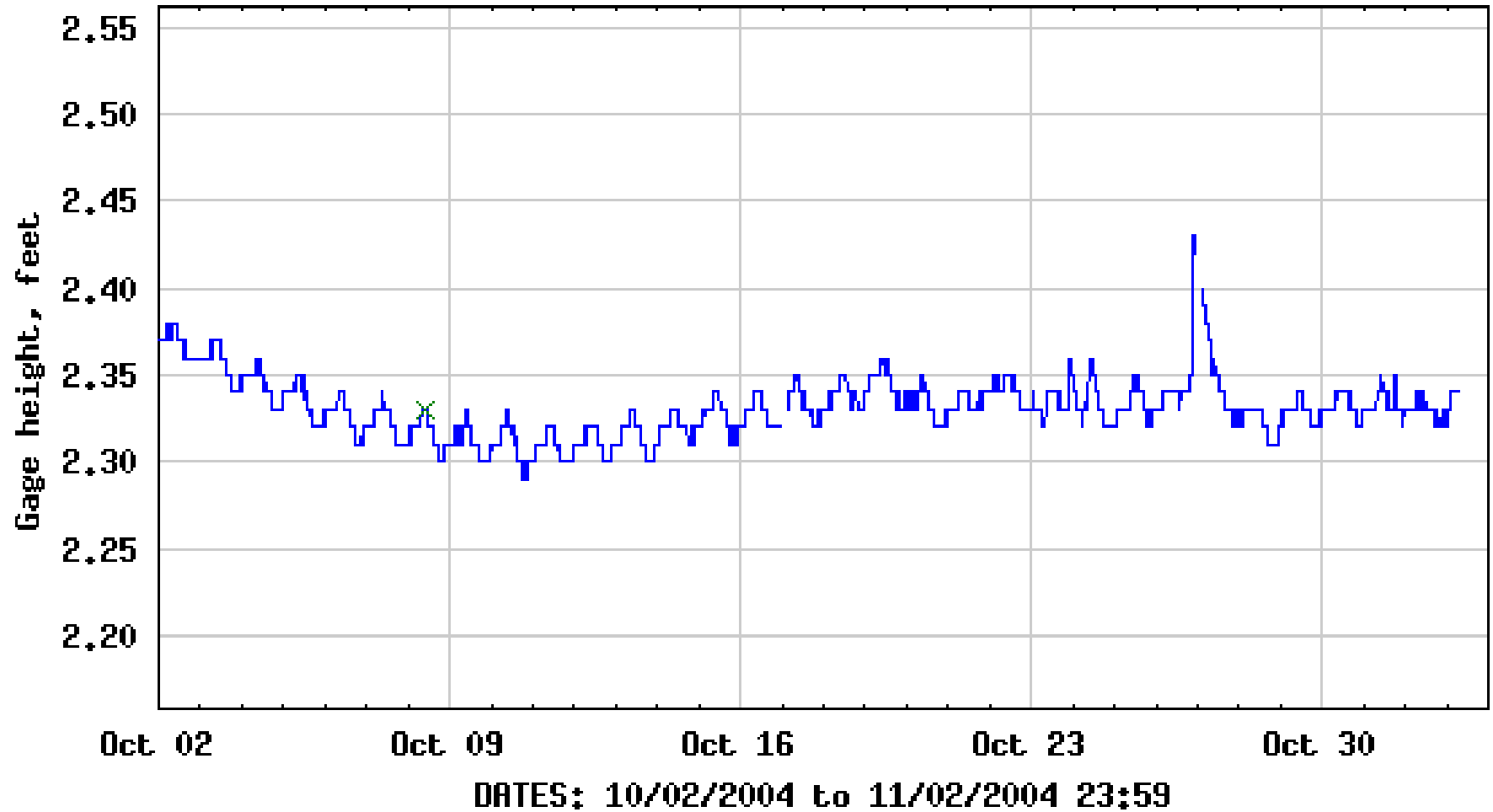
Really Acidic Streams

- Are Different, Most Toxic metals (Cd, Cu, Ni, Zn) Remain In Solution And Don't Show Big Diel Cycles
- But: Iron Is an Exception.
- Ferric Iron Is Photo-reduced (With The Help Of Microbes) To Ferrous Iron During The Day, And The Ferrous Iron Is Re-oxidized Back To Ferric Iron During The Night (Nimick).

What About Flow?

- Can be Diurnal Too.
- Small High Mountain Streams With Daytime Snowmelt and Night Freezes
- Small Desert Streams That Plants Suck Dry During the Day and That Resume Flowing at Night
- Streams Influenced by Night Rains or Irrigation.

USGS 09471000 SAN PEDRO RIVER AT CHARLESTON, AZ.



EXPLANATION

— GAGE HEIGHT

x MEASURED Gage height

Nutrients Except Nitrate Higher in Rising Limb

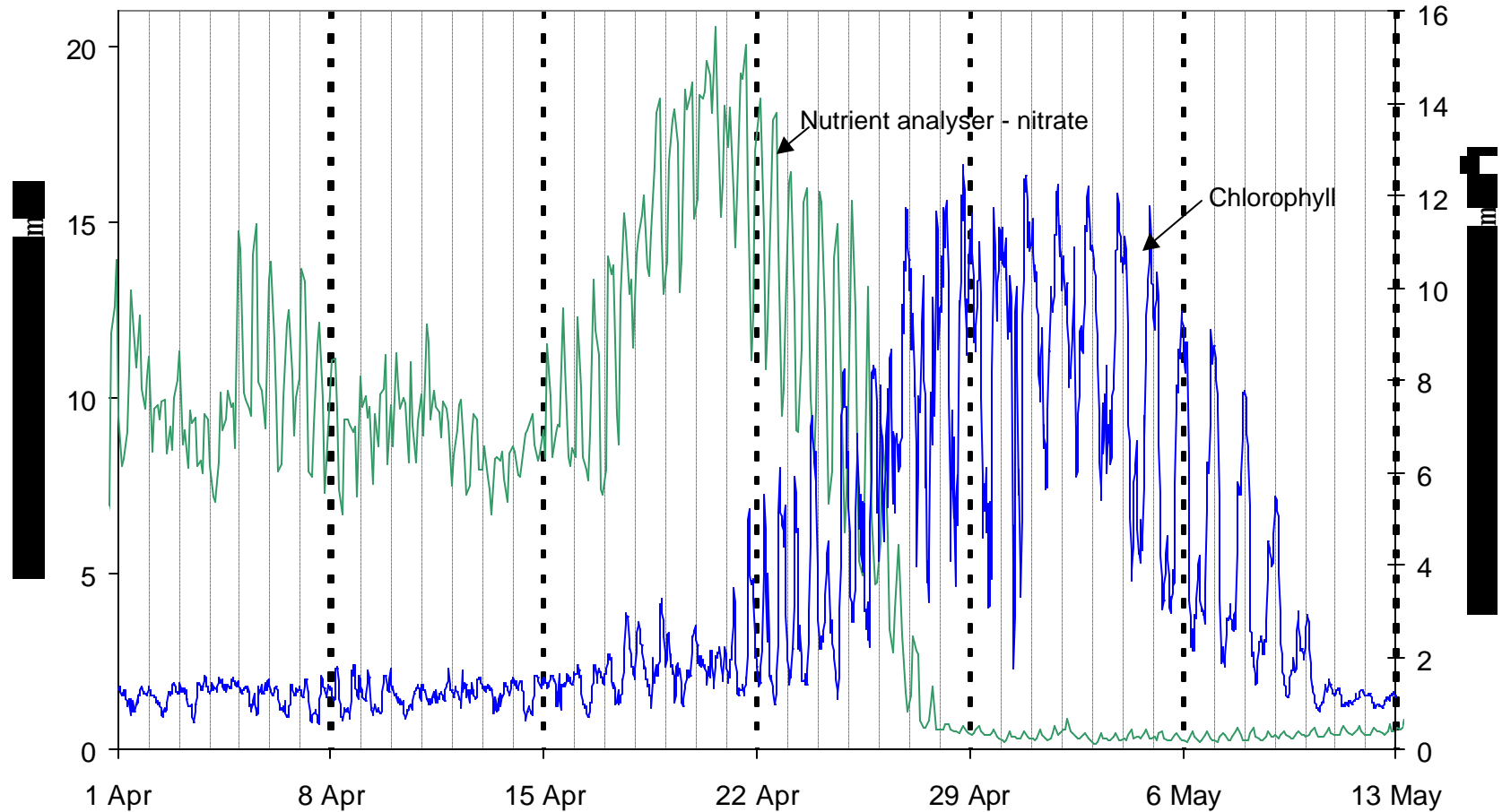
- Several Follow TSS And Turbidity Pattern
- Go Up With First Flush or Rising Limb:
- NH_4^+ Sometimes, TKN,
- Total Phosphorus (TP)
- Phosphate ($\text{PO}_4\text{-P}$)

EnviroTech EcoLAB

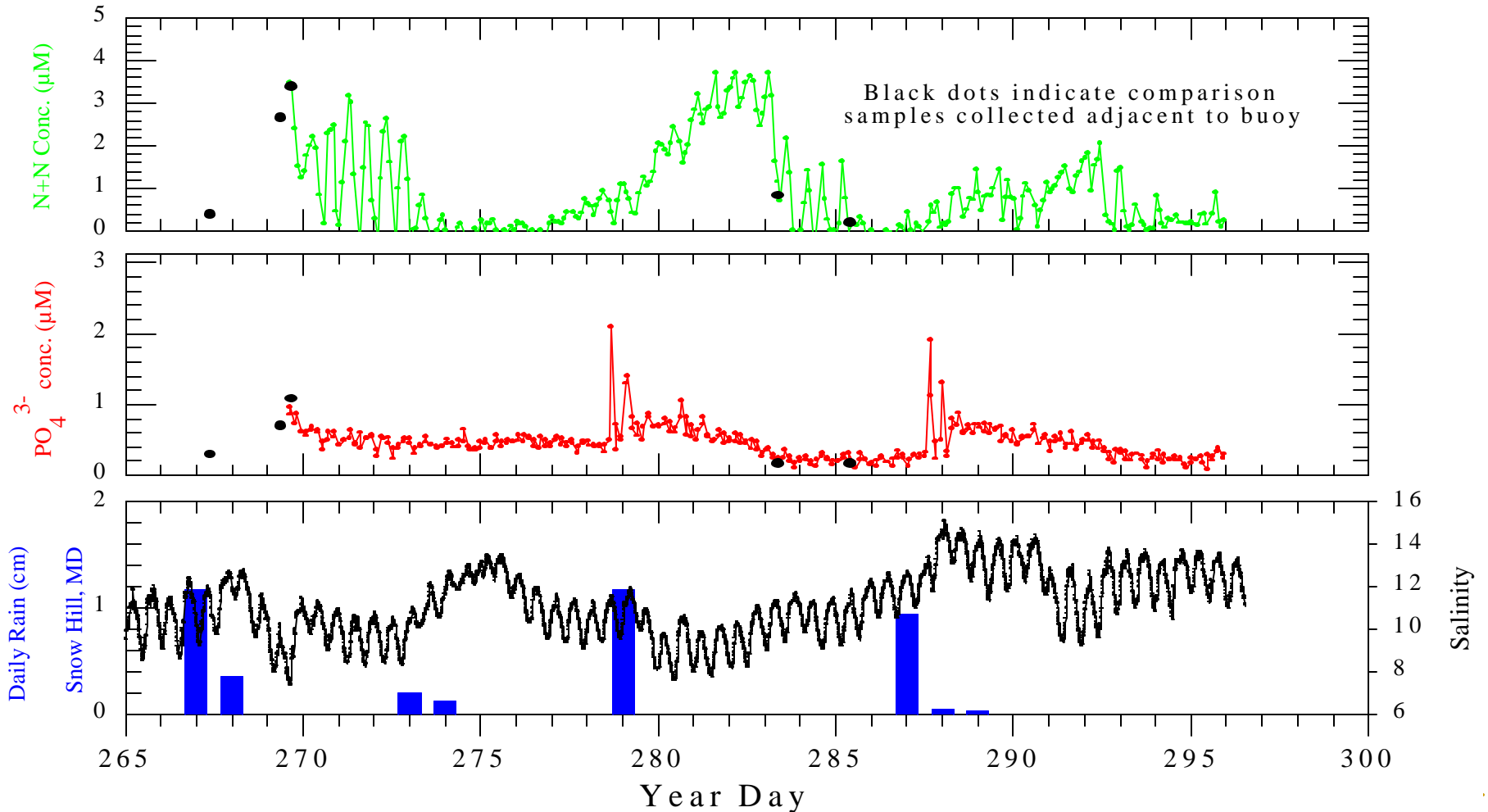
Multi-channel In-situ
Chemical Analyzer



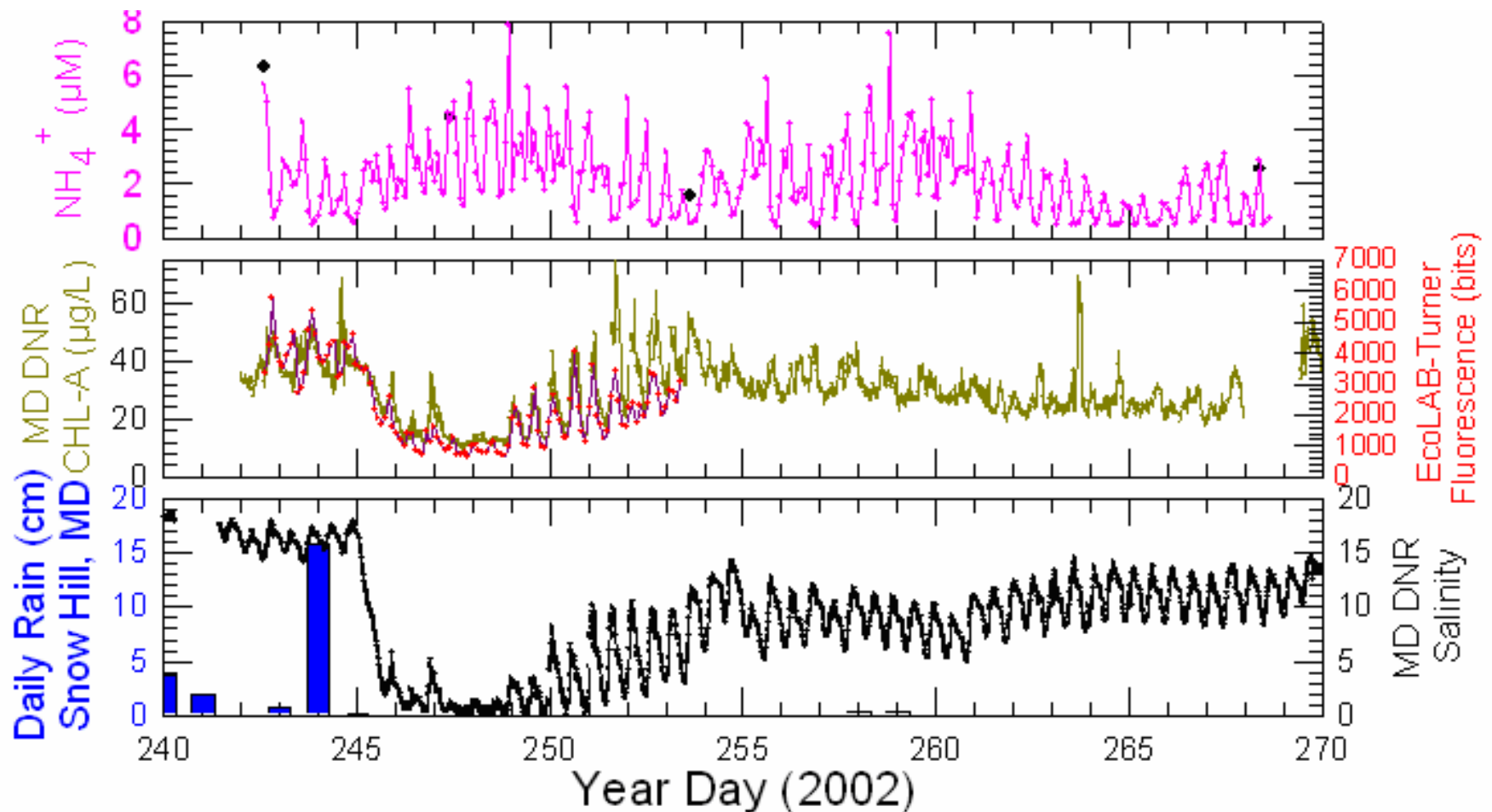
Nitrate Diel (then Nitrate Spike, Then Chlorophyll Spike Following)



NH₃, PO₄, RAIN, Salinity in MD



Rain = Ammonia Up a Bit, Chlorophyll & Salinity Down



Nitrates Are Consumed by Plants During the Day

- Even Though An Anion, Tends To Be Highest In The Dark
- Lowest In Late Afternoon
- Same For Phosphate
- Especially Where Nutrients are Low
- Daytime Plant Uptake Main Driver.

Happens at Many Sites

- Downstream of Golden POTW
- Some Lakes
- Open Oceans
- Coastal Waters
- But the night highs are not universal
- Y'all Be Careful Now: Tides and Storms

But Y'all Be Careful Now

- Many Exceptions
- Next Slide is an Exception
- Nitrates Seem to Be Lower At Night
- More Driven By Tides, & Then
- More Driven By a Big Rain Event

Nitrate Tidal Night Lows, Plus Flow (Rain/Dilution) Driven



USGS 07375690 Tangipahoa R. below Bedico Cr. nr Madisonville, LA



Provisional Data Subject to Revision

Limiting Nutrients

- Not Always As Simple As One Limiting Nutrient, Either N or P
- The Limiting Factors Can Change
- Sometimes in Fairly Short Times.
- Dissolved Inorganic Nutrients Not Good Surrogates For Total Nutrients
- Other Things Can Be Limiting
- Temperature, Light, Fe, Predation

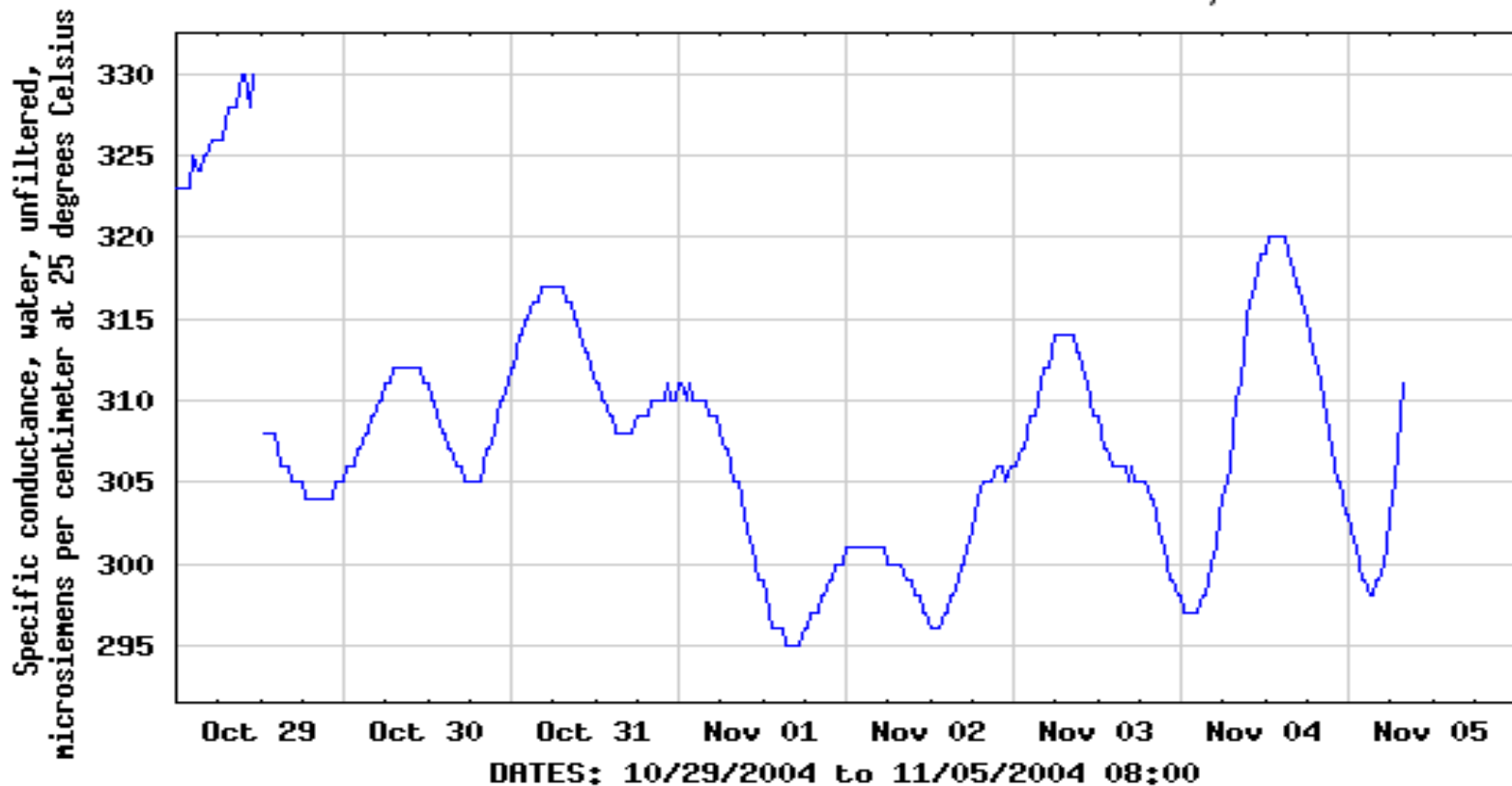
What About Conductivity?

- Harder to generalize.
- If the flow is coming and going diurnally
- Daytime plant consumption of H₂O,
- Daytime evaporation
- Tidal or other salinity diel changes.
- Areas with night rain or irrigation.
- Very site-specific.

Conductivity Sometimes Diel



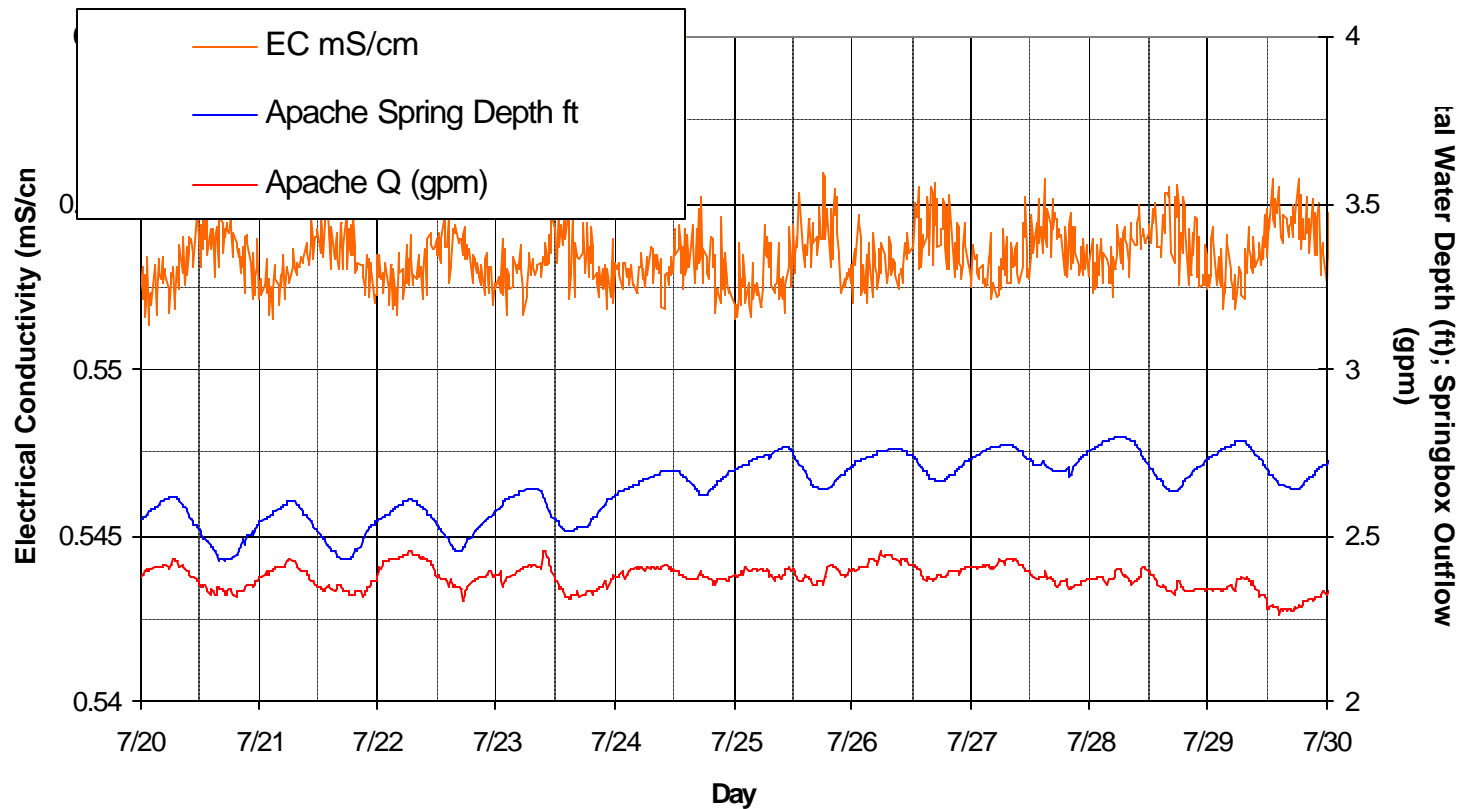
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO.



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Apache Spring Fort Bowie NHS Conductivity Diel Pattern

Fort Bowie National Historic Site - Apache Spring



Fear Of Variability In Benthic Macro-Invertebrates Is Overstated, Less Than Nutrients

Jeroen Gerritsen

Based on Work in Mid Atlantic States

Tetra Tech, Inc.



Variability is Not High If One

- Uses a Stable and Defined Index Period (For example, an Early Fall Collection Period).
- Minimizes Really Variable Metrics (No Abundance Or Ratio Metrics)
- Standardizes Collection Methods
- Estimates Variability!

Jeroen Gerritsen's Benthic Macroinvertebrate Conclusions

- Variability about ~10% within sites; ~20% within region
 - O/E ~20% in both site and region
 - Chemical measures: ~100% in sites
 - They Integrate Over Time, so Invertebrates Can Be Less Variable than Some Chemical Measures If One Takes Common Sense Precautions
-

I Would Add:

- **For Internal data comparability: Sample within a defined range of water temperatures.**
- **Catch invertebrates at a comparable stage of emergence and succession.**
- **Avoid wrong conclusions related early snow melt vs. late snow melt, hot summer vs. cold**



Minimize Other Sources of Variability That Would Obscure Detecting Trends

- Sample During Narrow Index Periods
- Sample in Stated Micro Habitats
- Use Stratified Random Sampling
- Complexity You Don't Have Can't Fail (Burt Rutan).
- So Keep It Simple!

There Are Other Myths to Bust

- Measurement Precision Simply Has to Be Smaller than True Environmental Variation.
- No! At Least 5 X Smaller as SD.
- If Two Labs Try To Measure Chlorophyll *a* Exactly The Same Way, And
- If One Gets An Answer That Represents A 147% RPD Vs. The Other: Not Insignificant. See Irwin Chlorophyll Handout.

Y'all Be Careful Now Parameters

- TP, TKN, Ammonia
- Chlorophyll: A Data Comparability and Reproducibility Nightmare (see Handout)
- Turbidity: USGS Codes the Data to Specific Instruments
- Some Pesticides: Huge Systematic Error/bias
- Physical Habitat Estimates
- May Vary By Sites and Labs

A Key For Trends: The Sampling Time

- Time Period Apt to Bust a Standard.
- Use Worst-case Sampling Index Period.
- Late Night Or Just Before Sunrise For;
- Cu, Zn, Cd, Cation ++ Metals,
- Nutrients, Dissolved oxygen,
- pH Decreasing And Approaching “Too-low” Thresholds.

Other Worst-Case Times:

- Late afternoon (still strong sun) for arsenic, temperature, or pH approaching “too-high” thresholds, or nutrients approaching “too-low” thresholds.
- Worst case may include a seasonal component: LATE SUMMER, hot, low-flow NIGHTS for low oxygen downstream of Boulder POTW.

Statistical Solutions

- For General Stats, Use Helsel Text Book on the Internet (see Part B).
- If you have NonDetects, Use Different Stats for Different Percentages of NonDetects (see **D. Helsel. 2004. Nondetects and Data Analysis: Statistics for Censored Environmental Data. Wiley. 288 pp.).**

For Trends

- If Seasonal Change is the Main Source of Variability:
 - Use Seasonal Kendall test for Trends (See Helsel Guidance on Web).
 - Sample at Same Time of Day
 - If Seasonal Not a Problem, use **Mann-Kendall test**
-

Reality Check with Summary Stats

- If you have picked your collection periods right and you have enough data:
- Plot average or median yearly values
- Regressions Can Sometimes Be Used, Usually on Log Transformed Data.
- Many Caveats (see Helsel).

Bottom Line:

Y'all Be Careful Now!